GSFC 429-03-02-24

# NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) PREPARATORY PROJECT (NPP)

# SPACECRAFT HIGH RATE DATA (HRD) RADIO FREQUENCY (RF) INTERFACE CONTROL DOCUMENT (ICD) TO THE DIRECT-BROADCAST STATIONS

December 2, 2003

**Check the NPP CCR website at http://nppcm.gsfc.nasa.gov/ccr/npp to verify that this is the correct version prior to use.**

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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Approved By:

*Original signed by* 05/05/04

Don Hood Date
BATC NPP Program Manager

*Original signed by* 05/10/04

Fred Ricker Date
NPOESS Program Director

*Original signed by* 01/12/04

Daniel DeVito Date
NPP Systems Manager

*Original signed by* 03/03/04

James Schaeffer Date
NPOESS Chief Systems Engineer

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

INTEGRATED PROGRAM OFFICE
SILVER SPRING, MARYLAND

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**Preface**

The National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) Spacecraft Radio Frequency (RF) Interface Control Document (ICD) defines all X-band High Rate Data (HRD) communication links between NPP Spacecraft and Direct Broadcast Users.

As designated lead center for the NPP Spacecraft, the Goddard Space Flight Center (GSFC) NPP Project Office (Code 429) will maintain configuration control of this document through its Configuration Control Board (CCB).

For the remainder of this document, the NPP Spacecraft may be referred to as the Spacecraft.

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# 1.0 INTRODUCTION

## 1.1 PURPOSE

This Interface Control Document (ICD) establishes performance requirements and defines and controls technical aspects of the High Rate Data (HRD) communications subsystem interfaces between the NPP Spacecraft and Direct Broadcast Users worldwide within line-of-sight view. The HRD provides real-time mission data (which includes instrument science data, instrument engineering data, and instrument telemetry data), and real-time Spacecraft housekeeping data via X-band downlink transmission.

## 1.2 INTERFACE RESPONSIBILITIES

Ball Aerospace and Technologies Corporation (BATC) under contract to Goddard Space Flight Center (GSFC) NPP Project Office is responsible for the NPP Spacecraft portion of the interface. Users of the Direct Broadcast Stations are responsible for meeting the requirements laid out in this ICD. Design requirements and parameters in this ICD are controlled by the GSFC NPP Project Office CCB, with inputs from GSFC NPP Project Personnel, Integrated Program Office (IPO), Shared System Performance Responsibility (SSPR), and BATC as appropriate

## 1.3 INTERFACE IDENTIFICATION

### 1.3.1 RF Link Definition

The communications subsystem interface defined and controlled by this ICD is the HRD Radio Frequency (RF) transmission link between the NPP Spacecraft and the Direct Broadcast Users as defined in Section 3. This ICD does not apply to the RF links of any other spacecraft/vehicle, tracking system, or dedicated ground terminal. Figure 1-1 depicts the RF links between the Spacecraft and its various interfaces.

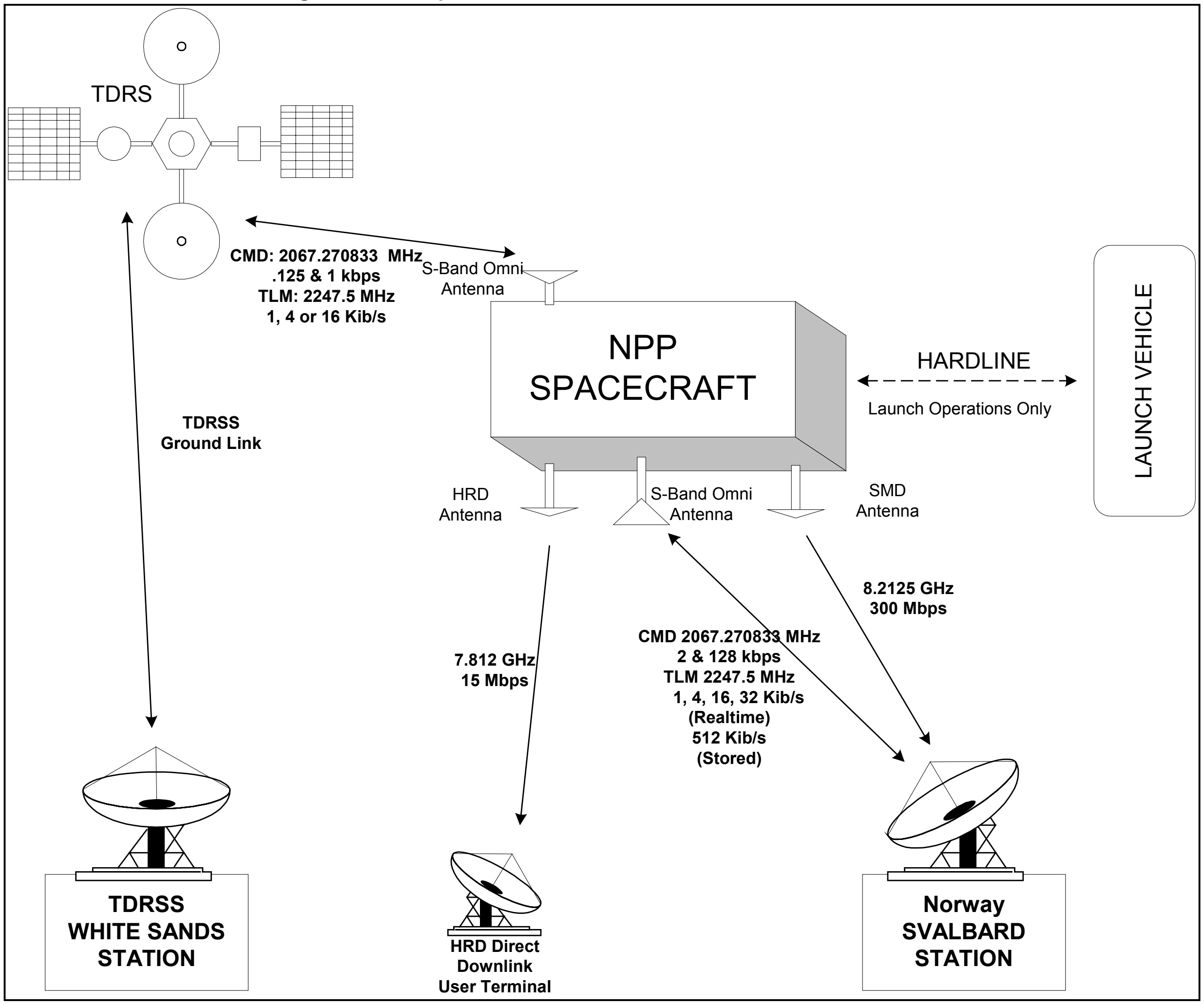
### 1.3.2 Link Calculations

The RF link calculations contained in Appendix A for the Spacecraft modes of operation are included only as supporting data and do not constitute a formal part of the RF ICD agreement. The Earth-coverage antenna patterns and downlink spectrum provided in Appendix B and Appendix C, respectively, are included for information purposes and are also not part of this RF ICD agreement.

### 1.3.3 Other RF Interfaces

The RF interfaces between the NPP Spacecraft and the Space Network, the NPP Spacecraft and S-Band at Norway ground station, and the NPP Spacecraft and X-Band at Norway ground station are included in separate RF ICDs. This ICD provides the definition of the NPP spacecraft to Command, Control and Communications Segment (C3S) interface mnemonic X_PP_C3-P3010.

*Figure 1-1. Spacecraft Communication Links*



# 2.0 DOCUMENTS

## 2.1 APPLICABLE DOCUMENTS

The following documents are applicable to the NPP Spacecraft.

a. GSFC 429-01-07-01, National Polar-Orbiting Environmental Satellite System (NPOESS) Preparatory Project (NPP) Satellite Requirements Specification, current version.
b. National Telecommunications & Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management, May/September 2000 Revisions.
c. Interface Requirements Document (IRD) For National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) Mission System to Direct Broadcast Users Interface, dated December 3, 2001.

## 2.2 REFERENCE DOCUMENTS

The following documents are reference documents applicable to the RF interface being controlled. These documents do not form a part of this ICD and are not controlled by their reference herein.

a. NPP Mission Data Format Control Book 549479
b. Consultative Committee for Space Data Systems (CCSDS) Recommendations for Telemetry Channel Coding, (CCSDS 101.0-B-5).
c. Consultative Committee for Space Data Systems (CCSDS) Recommendations for Advanced Orbiting Systems – Networks and Data Links: Architectural Specification (CCSDS 701.0-B-3)

## 2.3 OTHER RELATED DOCUMENTS

The following documents are listed for the convenience of the user. These documents do not form a part of this ICD and are not controlled by their reference herein.

a. PF568401, Product Functional Specification, HRD Transmitter

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# 3.0 COMMUNICATIONS INTERFACE REQUIREMENTS

## 3.1 HRD LINK OVERVIEW

### 3.1.1 General

The Spacecraft will use an Earth-coverage pattern antenna to provide downlink for Direct Broadcast Users. It provides real-time mission data (which includes instrument science data, instrument engineering data, and instrument telemetry data), and real-time Spacecraft housekeeping data. The data rate is 15Mbps at a nominal downlink frequency of 7812 MHz. In normal operations broadcast data will operate continuously providing real-time data to the Direct Broadcast Users.

### 3.1.2 Interface RF Links

The required RF communication links are as follows:

a. Mission data from Spacecraft-to-Direct Broadcast Users.

b. Pseudo Random Bit Stream (PRBS) for bit error rate (BER) measurements

## 3.2 INTERFACE FUNCTIONAL REQUIREMENTS

### 3.2.1 General

Paragraphs 3.2.2 to 3.2.5 describe the X-Band interface functional requirements that exist between the Spacecraft and the Direct Broadcast Users.

### 3.2.2 Overview

The HRD system hardware onboard the Spacecraft consists of two transmitters, one transfer switch, and one shaped reflector antenna. The antenna is designed to give Earth-coverage radiation pattern. Antenna patterns are shown in Appendix B for reference. The system is designed to always be on, with the ability to be turned off indefinitely. Figure 4-6 shows the architecture for the HRD system. The Direct Broadcast User Terminal demodulates and decodes the RF received from the Spacecraft communication subsystem. The Spacecraft-to-Earth station link distance ranges from 2835 km, at a ground station elevation angle of 5 degrees to 824 km at a station elevation angle of 90 degrees. Direct Broadcast Station support is dependent on favorable radio line-of-sight conditions when Direct Broadcast Station antenna elevation angle is greater than 5 degrees (above the local horizon).

### 3.2.3 Mission Data

Transmission of real-time payload data from the Spacecraft to Direct Broadcast Users of HRD occurs at 15 Mbps. Mission data will be formatted in accordance with Spacecraft requirements outlined in paragraph 4.3. The 15 Mbps is the Channel Access Data Unit (CADU) bit rate, measured after Reed-Solomon coding and pre-pending the Attached Sync Marker. After rate 1/2 convolutional coding is applied, the in-phase (I)- and quadrature-phase (Q)-channels are each modulated with 15 Msps (30 Msps total). Data from the HRD is selectable by Application Identification (APID) via table load. In all cases, fill on frames are added in order to maintain the 15 Mbps downlink rate.

### 3.2.4 Pseudo-Random Bit Stream (PRBS)

The satellite will generate pseudo-random bit stream test data as a test mode used for the purpose of bit error rate (BER) checking, as required. It is not a normal X-band downlink service.
NOTE:
The link analysis for the PRBS is not shown since the Mission Data link analysis is worst case.

### 3.2.5 Doppler Tracking and Ranging

The Direct Broadcast Stations must be able to handle a maximum Doppler shift of +/- 171.6 kHz at an elevation angle of 5 degrees, and a Doppler shift rate of 1.55 kHz/sec at an elevation angle of 90 degrees. This link will not provide a ranging capability.

## 3.3 COMMUNICATIONS PERFORMANCE CHARACTERISTICS

### 3.3.1 General

RF link performance requirements for the communications functional capability described in paragraph 3.2 are defined in this section. Direct Broadcast Station communications performance requirements are based on the presumption that the Spacecraft and Direct Broadcast Station each perform in accordance with the system performance parameters defined in Section 4.

### 3.3.2 Mission-data Channel BER

The maximum HRD downlink information BER for the mission data channel will be $1.83 \times 10^{-3}$, referenced to the input of a Reed-Solomon (R-S) Decoder on the ground. With R-S decoding at the Direct Broadcast terminal, the effective output mission data BER will be $10^{-8}$. The Interface Requirements Document (IRD) requires an $E_b/N_o$ of 4.4 dB, which is more stringent than the $10^{-8}$ BER requirement. Therefore the link analysis is performed using the $E_b/N_o$ requirement of 4.4 dB.

### 3.3.3 PRBS Test Channel BER

The maximum HRD downlink information BER for the PRBS test channel will be $1 \times 10^{-4}$, referenced to the output of the Viterbi decoder on the ground per the HRD IRD. Actual performance will be better than $10^{-5}$ based on the $E_b/N_o$ requirement of 4.4 dB.

## 3.4 SPACECRAFT/DIRECT BROADCAST STATION COMMUNICATION LINK (X-BAND DOWNLINK) MODES

The Spacecraft X-band downlink modes are shown in Table 3-1.

*Table 3-1. Spacecraft HRD Communications Modes*

| Service | Data Mode | Rate (Mbps) | Antenna (Polarization) | Modulation | I:Q Power Ratio |
|---|---|---|---|---|---|
| Direct Broadcast Users | HRD (mission data) | 15 | Earth-coverage antenna (RHCP) | QPSK | 1:1 |
| Direct Broadcast Users | PRBS | 15 | Earth-coverage antenna (RHCP) | QPSK | 1:1 |

# 4.0 HRD LINK INTERFACE CHARACTERISTICS

## 4.1 PURPOSE

This section specifies the functional design of the RF HRD link. Pertinent Spacecraft and Direct Broadcast Station communications signal designs and system performance requirements are also specified.

## 4.2 LINK FUNCTIONAL DESIGNS: SPACECRAFT-TO-DIRECT BROADCAST STATION HRD DOWNLINK

### 4.2.1 General

The HRD transmitter will be used to transmit the data for this link. Baseband characteristics will be in accordance with Table 4-1. The Earth-coverage antenna provides 15 Mbps data to the Direct Broadcast Users. The HRD system is designed to transmit data at all times, however, it can be turned off indefinitely if the need arises.

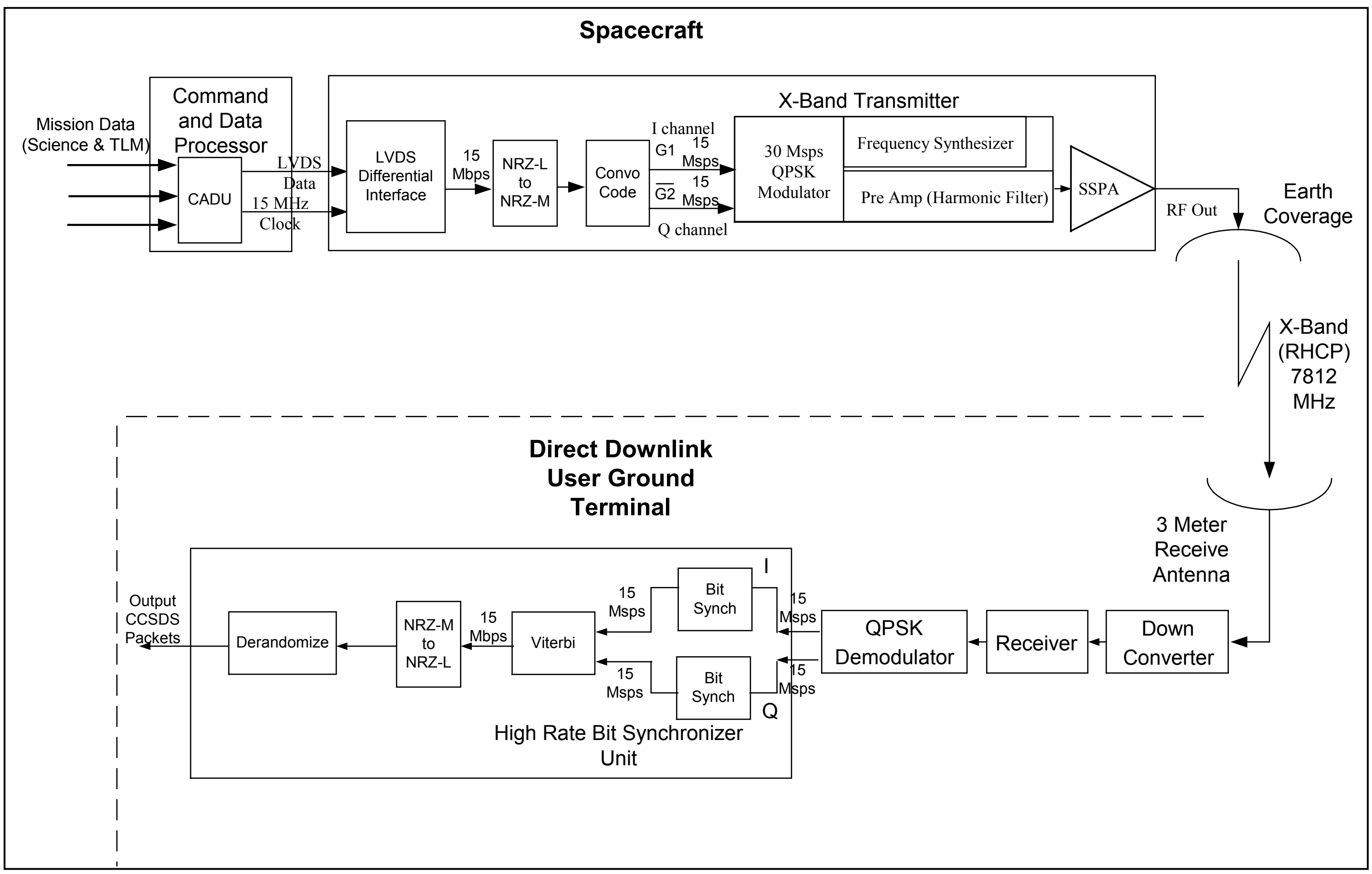


*Figure 4-1. Spacecraft-to-Direct Broadcast Station Downlink Configuration (Mission Data)*

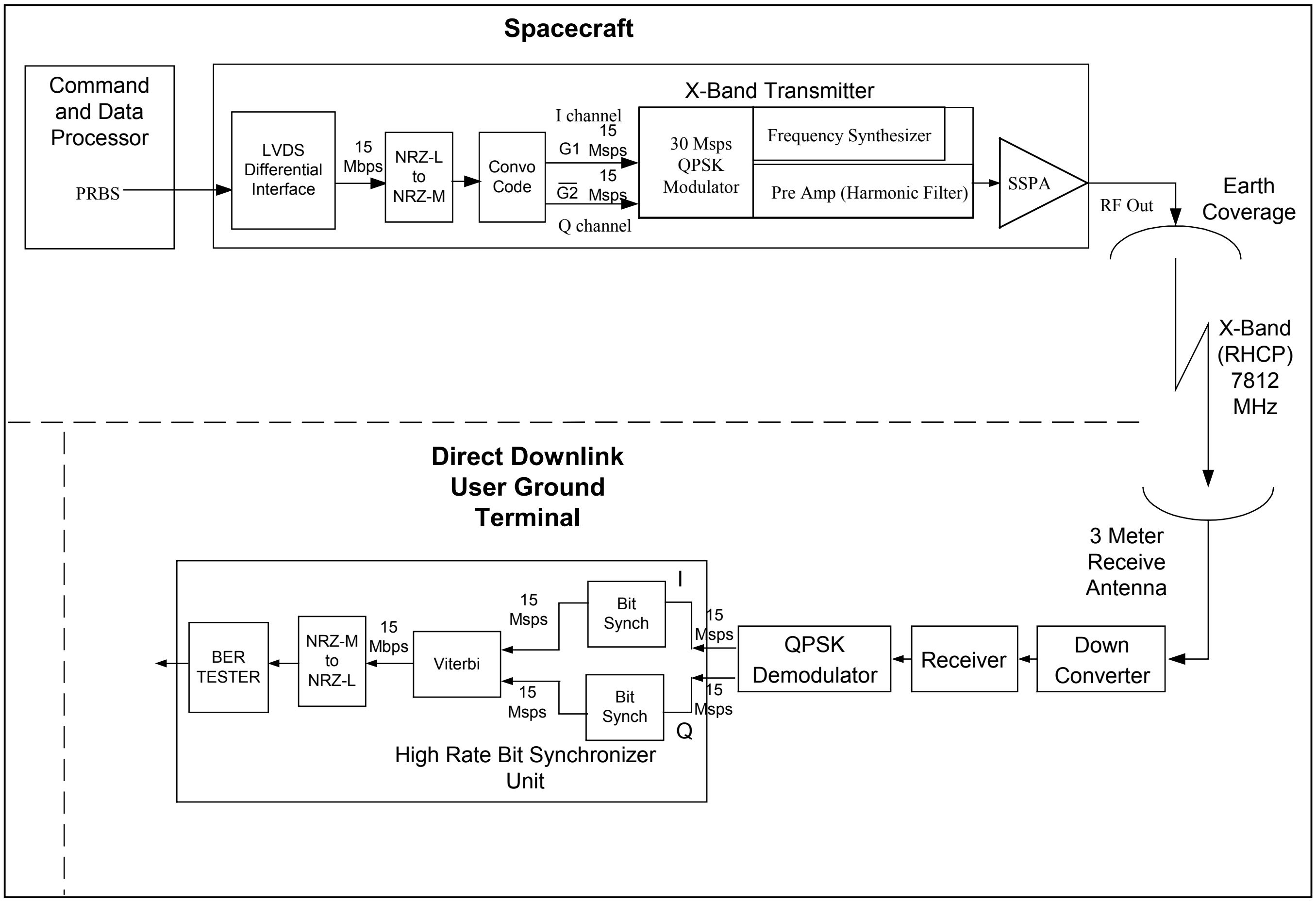


*Figure 4-2. Spacecraft-to-Direct Broadcast Station Downlink Configuration (PRBS Mode)*

### 4.2.2 Functional Description

The functional interface of the Mission Data link will be as shown in Figure 4-1, and the functional interface of the PRBS test bit stream link will be as shown in Figure 4-2.

a. The Spacecraft mission data is sent from the Command and Data Processor (CDP) to the HRD transmitters. The signal from the CDP is Low Voltage Differential Signal (LVDS) in a Non-return to Zero Level (NRZ-L) format.
b. The data is then converted from NRZ-L to Non-return to Zero Mark (NRZ-M) format and is then convolutionally encoded.
c. The convolutional encoder outputs are split with G1 on the I- and G2 (inverted) on the Q-channel. The I- and Q-channel data is Quadrature Phase Shift Keying (QPSK) modulated onto the X-band carrier with an I/Q-channel power ratio of 1:1 as shown in Figure 4-1 and Figure 4-2. The X-band carrier is derived from a Temperature Compensated Crystal Oscillator (TCXO).
d. These data streams QPSK modulate onto a 7812 MHz carrier. The resulting RF output is amplified to 7 watts minimum out of the transmitter. The link uses the Earth-coverage antenna to transmit to Direct Broadcast Users.

#### 4.2.2.1 Data Formatting for Mission Data (see Figure 4-6)

The order of data formatting is as follows: (Details of A and B are covered in the Mission Data Format Control Book, 549479)

a. CCSDS format (into Coded Virtual Channel Data Units (CVCDU's) with Reed Solomon (R-S) (255,223), I=4)
b. Randomize CVCDU's (see Section 4.3.4)
c. CCSDS format into Channel Access Data Units (CADU's) by adding sync (see Section 4.3.4)
d. Differential encode
e. Convolutional encode (as called out in paragraph 4.3.6)—the G1 output will be routed to the I channel of the HRD transmitter, and the G2 (inverted) output will be routed to the Q channel of the HRD transmitter.

Data formatting for PRBS mode is as follows (see Figure 4-2):

a. All zeroes input
b. Randomize the input by using the following bit transition generation function (refer to CCSDS 101.0-B-5 Recommendations for Telemetry Channel Coding):

$$h(x) = x^8 + x^7 + x^5 + x^3 +1$$

c. Differential encode
d. Convolutional encode (as called out in paragraph 4.3.6)—the G1 output will be routed to the I channel of the HRD transmitter, and the G2 (inverted) output will be routed to the Q channel of the HRD transmitter.

#### 4.2.2.2 Direct Broadcast User Ground station Functionality

At the Direct Broadcast Users Receive Ground Station, the input signal from the receive antenna is down converted before being input to the QPSK receiver/demodulator. The QPSK receiver/demodulator demodulates the down converted signal into separate I- and Q-channel data streams with NRZ-M format. Following QPSK demodulation, the bit synchronizers recover symbol clock, the data is Viterbi decoded, and converted to NRZ-L format. After being converted to NRZ-L the data will be de-randomized. Table 4-1 contains minimum performance requirements for the Direct Broadcast Users Ground Station.

*Table 4-1. HRD-band Downlink Baseband and RF Signal Parameter Requirements Versus Capability and Interface Characteristics (Numbers are placeholders only)*

| Parameter | Requirement/Source | | | Capability | | Comply |
|---|---|---|---|---|---|---|
| Transmit Center Frequency | 7812 ±0.03 MHz | | | 7812 ±0.03MHz | | Yes |
| Data Rate | 15,000,000 bps +/- 6 kbps | | | 15,000,000 bps +/- 6 kbps | | Yes |
| Polarization | RHCP | | | RHCP | | Yes |
| Axial Ratio | Ground Elevation Angle (deg) | Angle from Spacecraft Antenna Boresight (deg) | Axial Ratio (dB) | Angle from Spacecraft Antenna Boresight (deg) | Axial Ratio (dB) | |
| | 5 | 61.9 | | 61.9 | TBD | |
| | 40 | 42.7 | | 42.7 | | |
| | 70 | 17.6 | | 17.6 | | |
| | 90 | 0 | | 0 | | |
| Coverage | ±62° | | | ±62° (1) | | Yes |
| Minimum EIRP (dBm) | Ground Elevation Angle (deg) | Angle from Spacecraft Antenna Boresight (deg) | EIRP (dBm) | Angle from Spacecraft Antenna Boresight (deg) | EIRP (dBm) | |
| | 5 | 61.9 ±0.1 | 42.8 | 61.9 ±0.1 | TBD | |
| | 40 | 42.7 ±0.1 | 33.6 | 42.7 ±0.1 | | |
| | 70 | 17.6 ±0.1 | 30.8 | 17.6 ±0.1 | | |
| | 90 | 0 ±0.1 | 30.3 | 0 ±0.1 | | |
| Data Modulation | QPSK | | | Compliance | | Yes |
| Data Format, Modulator Output | NRZ-M output | | | Compliance | | Yes |
| Assigned Bandwidth (-20 dB) | ≤30 MHz | | | 30 MHz | | Yes |
| Gain Slope over $f_c$ ±15 MHz | ≤0.2 dB/MHz | | | Angle from Spacecraft Antenna Boresight (deg) | Gain Slope | |
| | | | | 61.9 | TBD | |
| | | | | 43.6 | | |
| | | | | 17.9 | | |
| | | | | 0 | | |
| Gain Flatness over $f_c$ ± 15MHz | <2.0 dB p-p | | | <2.0 dB p-p | | Yes |
| Phase Non-linearity over $f_c$ ± 15 MHz | <6 degrees p-p | | | <6 degrees p-p | | Yes |
| I/Q Power Ratio (Nominal) | 1:1 | | | 1:1 | | Yes |
| I/Q Power Ratio Tolerance | ≤0. 5 dB | | | ≤0. 5 dB | | Yes |
| QPSK Phase Imbalance | ≤4.5° | | | ≤4.5° | | Yes |
| QPSK Gain Imbalance | ≤1 dB p-p | | | ≤1 dB p-p | | Yes |
| Data Asymmetry | ≤3% | | | ≤3% | | Yes |
| Data Bit Jitter | ≤1% | | | ≤1% | | Yes |
| Phase Noise (Offset from Carrier) 100 Hz – 40 MHz<br>Spurious Phase Modulation | ≤2.0 degrees RMS<br>≤2.0 degrees RMS | | | ≤2.0 degrees RMS<br>≤2.0 degrees RMS | | Yes |
| AM/PM | ≤10°/dB | | | <10°/dB | | Yes |
| I/Q Data Skew | < ±5% of bit period | | | < ±5% of bit period | | Yes |
| Operational Duty Cycle, Science Mode | 100% | | | 100% | | Yes |
| Service Interruption | None | | | HRD can be commanded off or on | | Yes |
| Frequency Stability Over all conditions | $\pm 1 \times 10^{-5}$ | | | $\pm 1 \times 10^{-5}$ | | Yes |
| HRD System BER | $1 \times 10^{-8}$ (link margin ≥1 dB) | | | $1 \times 10^{-8}$ | | Yes |
| Untracked Spurious PM (100 Hz to 40 MHz) | ≤2° | | | ≤2° | | Yes |

<table>
<tr><th>Parameter</th><th colspan="2">Requirement/Source</th><th colspan="2">Capability</th><th>Comply</th></tr>
<tr><td>Carrier Suppression</td><td colspan="2">≥30 dBc</td><td colspan="2">≥30 dBc</td><td>Yes</td></tr>
<tr><td>Spurious Emissions (out-of-band)</td><td colspan="2"><-53dBc/Hz</td><td colspan="2"><-53dBc/Hz</td><td>Yes</td></tr>
<tr><td>Ground Station Pointing Loss</td><td colspan="2">≤1 dB</td><td colspan="2">≤1 dB</td><td>Yes</td></tr>
<tr><td>Ground Station Implementation Loss</td><td colspan="2">≤2.5 dB</td><td colspan="2">≤2.5 dB</td><td>Yes</td></tr>
<tr><td>Ground Station Multipath Loss at 5° Elevation angle</td><td colspan="2"><0.2 dB</td><td colspan="2"><0.2 dB</td><td>Yes</td></tr>
<tr><td rowspan="2">Ground Station G/T (dB/K)<br>3 meter antenna<br><br>Reference: IRD for NPP Mission System to Direct Broadcast Users Interface</td><td>Ground Elevation</td><td>G/T (dB/K) (2)</td><td>Ground Elevation</td><td>G/T (dB/K) (2)</td><td rowspan="2">Yes</td></tr>
<tr><td>5°<br>40°<br>70°<br>90°</td><td>22.7<br>23.59<br>23.65<br>23.66</td><td>5°<br>40°<br>70°<br>90°</td><td>22.7<br>23.59<br>23.65<br>23.66</td></tr>
<tr><td colspan="6">NOTE<br>1. Allows for +/-0.3 degree pointing uncertainty<br>2. The link availability is dependent upon actual location of the User Terminal. Reference the Link Analysis in Appendix A.</td></tr>
</table>

## 4.3 BASEBAND SIGNAL CHARACTERISTICS

### 4.3.1 General

This paragraph provides a description of the baseband signal characteristics of the HRD downlink signal to the Direct Broadcast Users. The formatting process is illustrated in Figure 4-7. Further detail of the CCSDS structure is covered in the NPP Mission Data Format Control Book 549479.

### 4.3.2 Mission-data Baseband Signal Parameters

The Spacecraft HRD downlink baseband signal parameters for the mission data are contained in Table 4-1, along with the modulation and RF signal parameters.

### 4.3.3 HRD Formatter

The CDP shall provide a HRD Formatter function that allows CCSDS CADUs to be generated from CCSDS Virtual Channel Data Units (VCDU) provided by the CDP flight software (FSW). The HRD Formatter shall support CCSDS Grade 2 telemetry service as defined in CCSDS 701.0-B-3 Paragraphs 2.3.3 and 2.4.1.2.f. The Reed-Solomon code is standard CCSDS 255,223 with interleave depth 4. A block diagram of the HRD Formatter and transmitter is shown in Figure 4-6. Fill frames with Virtual Channel 63 are added as necessary at the VCDU level in order to maintain a constant 15 Mbps formatted downlink rate as shown in the diagram. In order to perform BER tests, an all 0's input may be switched into the system prior to the randomizer as shown in the Figure 4-6.

### 4.3.4 HRD Randomizer

The HRD Formatter shall provide a function to randomize telemetry data contained in CVCDUs. The randomization process shall be Enable/Disable selectable by command.

The data shall be randomized in compliance with CCSDS 101.0-B-5, Paragraph 6.2, when the HRD data randomizer is enabled. The HRD Randomizer configuration is illustrated in Figure 4-3. The Logic for the HRD data randomizer is shown in Figure 4-4. The data shall bypass this process when the HRD data randomizer is disabled. The 32-bit synchronization marker is added to each Data Unit in order to complete the CADU format.

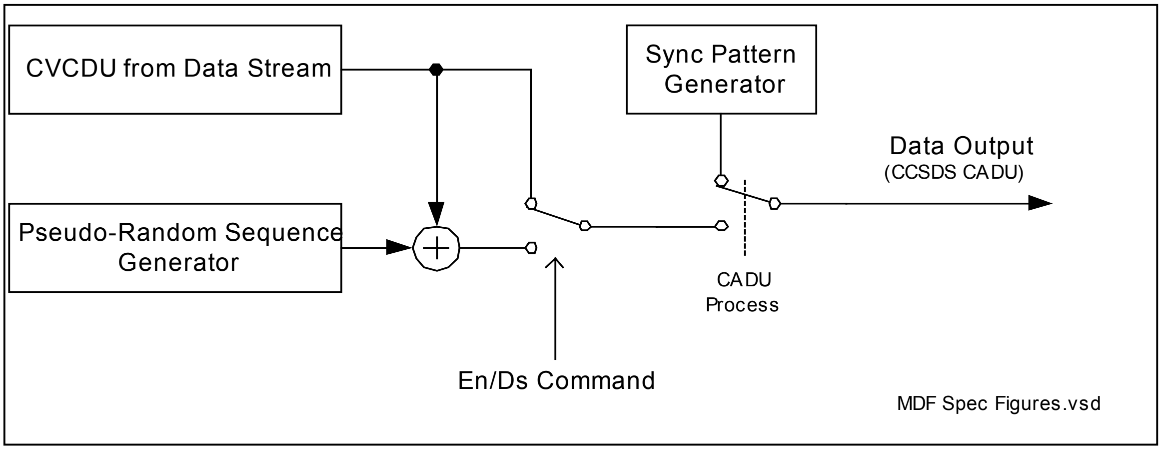


*Figure 4-3 HRD Randomizer Configuration*

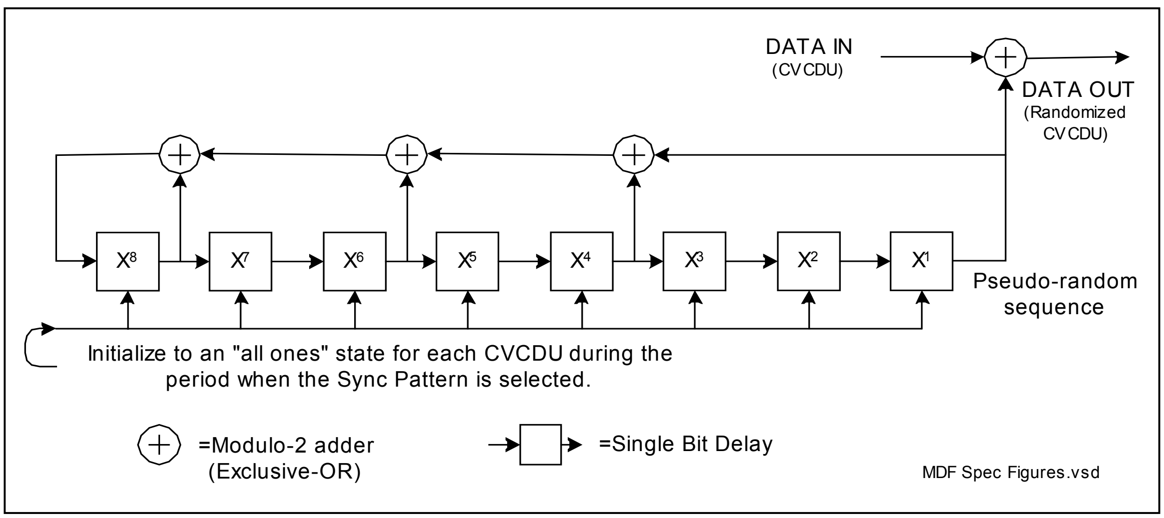


*Figure 4-4 HRD Randomizer Logic Diagram*

### 4.3.5 Data and Symbol Signal Formats

After randomization and insertion of the frame synchronization marker, the signal is serially converted from NRZ-L to NRZ-M.

### 4.3.6 Convolutional Coding

The Spacecraft will encode the HRD stream with a rate ½, constraint length 7 convolutional coding as defined in CCSDS 101.0-B-5. Figure 4-5 shows the encoder block diagram. The convolutional encoder outputs are routed with G1 to the I channel of the modulator and G2 (inverted) to the Q channel of the modulator.

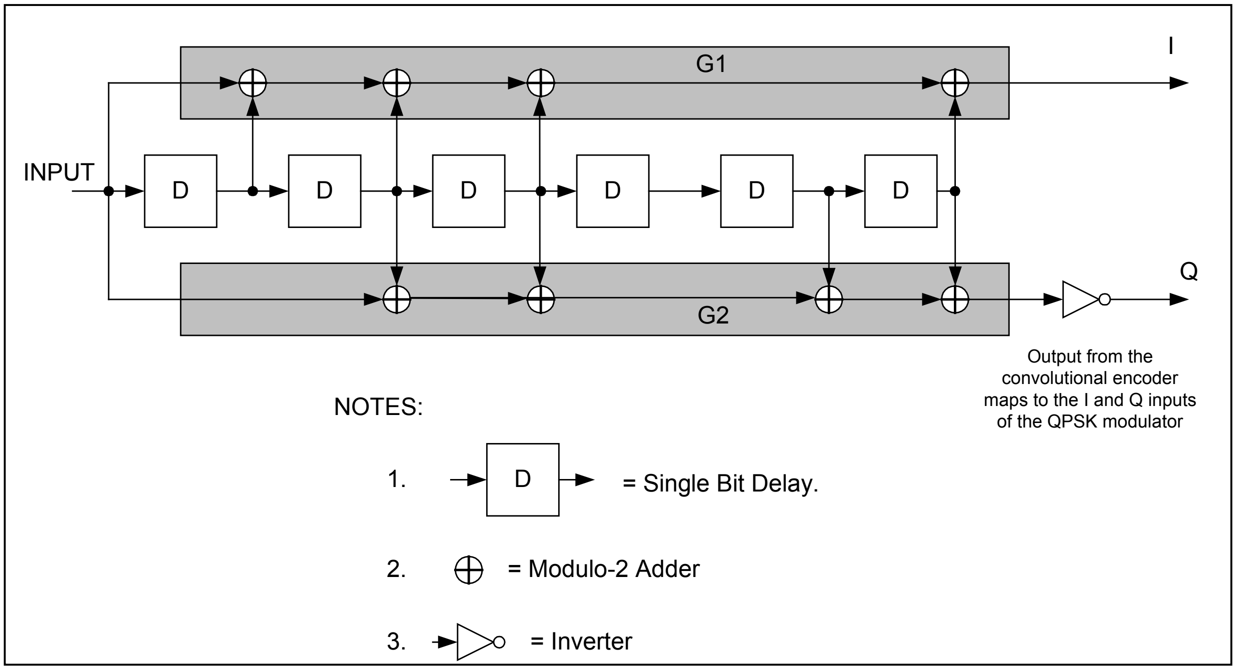


*Figure 4-5. CCSDS Recommendation for Telemetry Channel Coding*

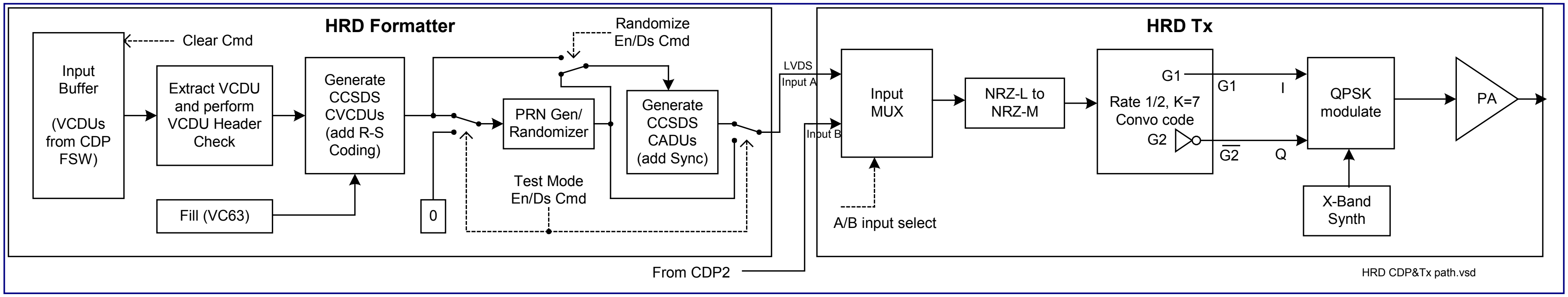


*Figure 4-6 HRD Formatter/Transmitter Block Diagram*

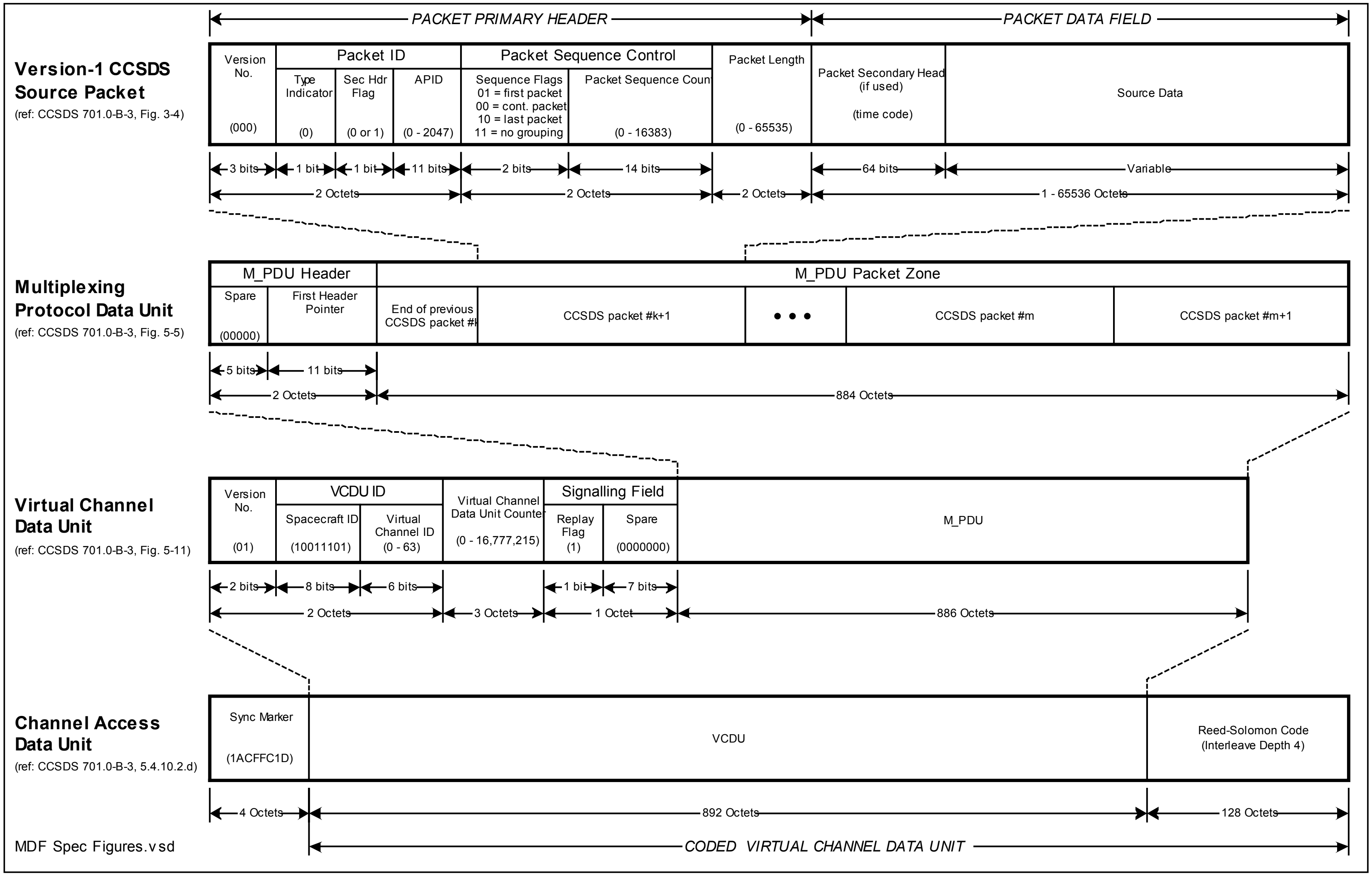


*Figure 4-7 CCSDS Grade 2 HRD Formatting*

## 4.4 RF SIGNAL CHARACTERISTICS

### 4.4.1 General

For the Spacecraft-to-Direct Broadcast Users HRD 15 Mbps downlink, balanced QPSK modulation (channel power ratio of 1:1) is used.

### 4.4.2 Signal Characteristics

The signal characteristics of the HRD downlink are in accordance with Table 4-1. QPSK modulation is employed. The X-band carrier is modulated by the I- and Q-baseband signals. The HRD downlink uses an Earth-coverage antenna on the Spacecraft. The I channel leads the Q channel by 90 degrees.

#### 4.4.2.1 Signal Characteristics-DSN protection

Deep Space Network (DSN) interference criteria of –255.1 dBw/m$^2$ Hz from 8400 to 8450 MHz is met by filtering the HRD transmitter appropriately in this band.

Table 4-2 shows the analysis

*Table 4-2 DSN Flux-Density Analysis*

| Parameter | Power | Units | Reference |
|---|---|---|---|
| HTX Max Power | 14 | watts | Maximum Output Power |
| Power in dBW | 11.46 | dBW | |
| passive loss | -1 | dB | Lowest case loss |
| Ant Gain | 6.5 | dBi | Worst case antenna gain (SC not nadir pointed) |
| EIRP | 16.96 | dBW | (sum of above) |
| RF vs. unmodulated | -71.8 | dB | $= V_S^2 T_S$ |
| (Sin X)/X loss | -40.00 | dB | $\left(\frac{\sin \pi f T_s}{\pi f T_s}\right)^2$ |
| filter loss | -33 | dB | Transmitter Filter at 39th sideband |
| Spreading factor | -129.3 | dB | 825 km distance (NPP directly over DSN) |
| total | **-257.11** | dBW/m$^2$ per Hz | |
| requirement | -255.1 | dBW/m$^2$ per Hz | SA1157 (& HRD IRD) |
| **Margin** | **2.01** | dB | Worst Case |

Check the NPP CCR website at http://nppcm.gsfc.nasa.gov/ccr/npp to verify that this is the correct version prior to use.

4.4.2.2 Signal Characteristics- NTIA bandwidth

The filtering of the HRD downlink will be within the NTIA bandwidth mask as shown in Figure 4-8.

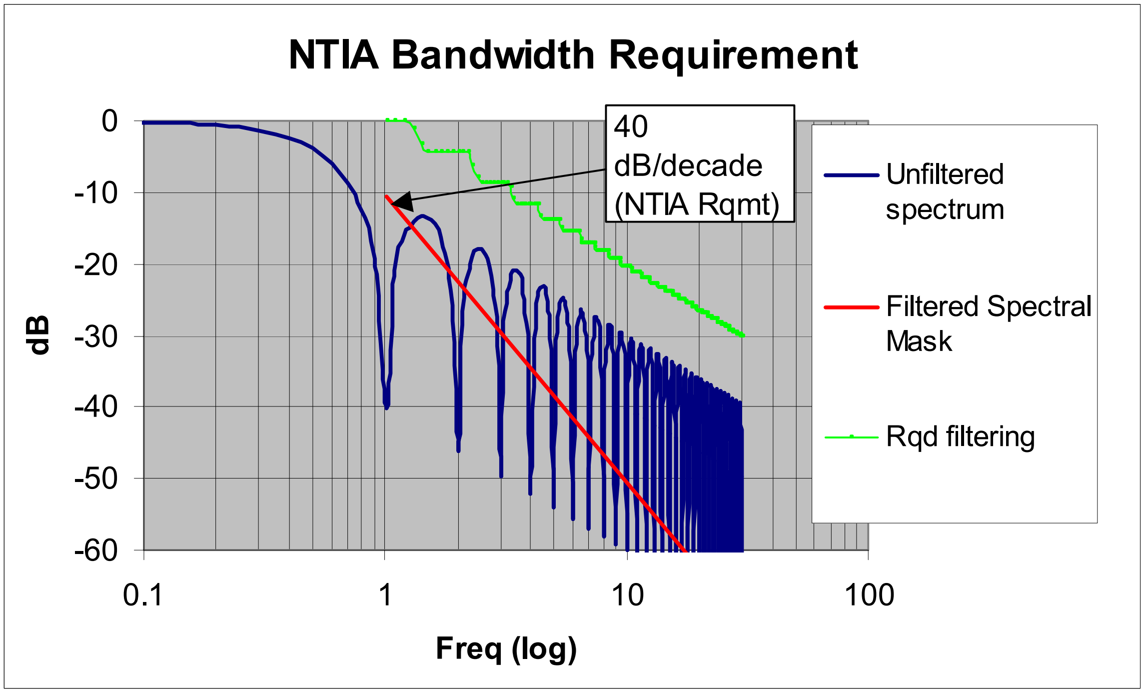


*Figure 4-8 NTIA Bandwidth Requirement*

4.4.2.3 Filter Characteristics

A pre-final amplifier filter is employed to meet the requirement of 4.4.2.1 and 4.4.2.2. The filter characteristic is shown in Figure 4-9. The spectral output is shown in Appendix C.

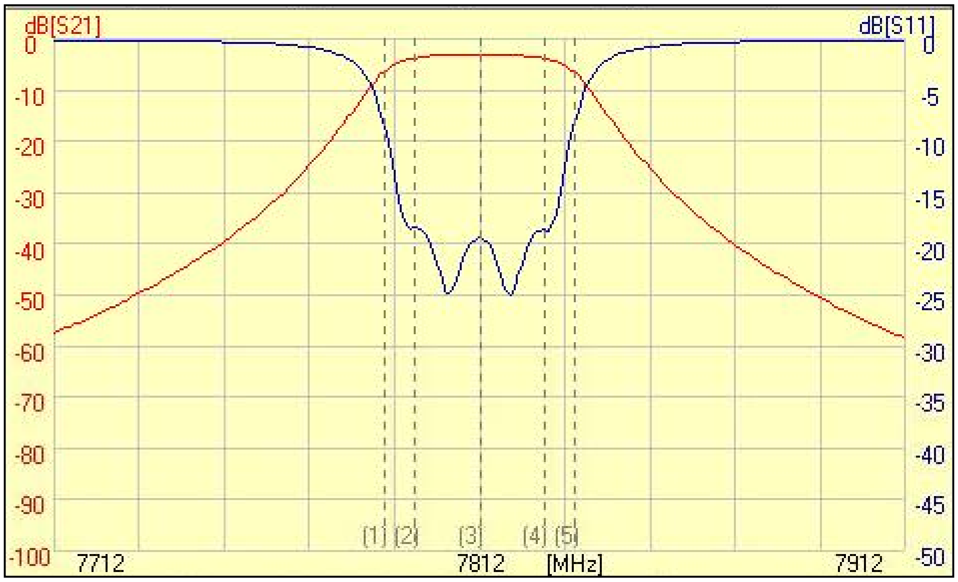


*Figure 4-9 HRD Pre-final RF Filter*

### 4.4.2.4 Signal Characteristics-Doppler Shift

The Spacecraft will be traveling at a velocity of ~7.44 km/sec at an altitude of 824 km. This results in a maximum doppler shift of +/-171.6 kHz at an elevation angle of 5 degrees. Figure 4-10 shows the doppler shift rate as the Spacecraft travels over the different elevation angles. The max rate of change of 1.55 kHz/sec occurs at an elevation angle of 90 degrees.

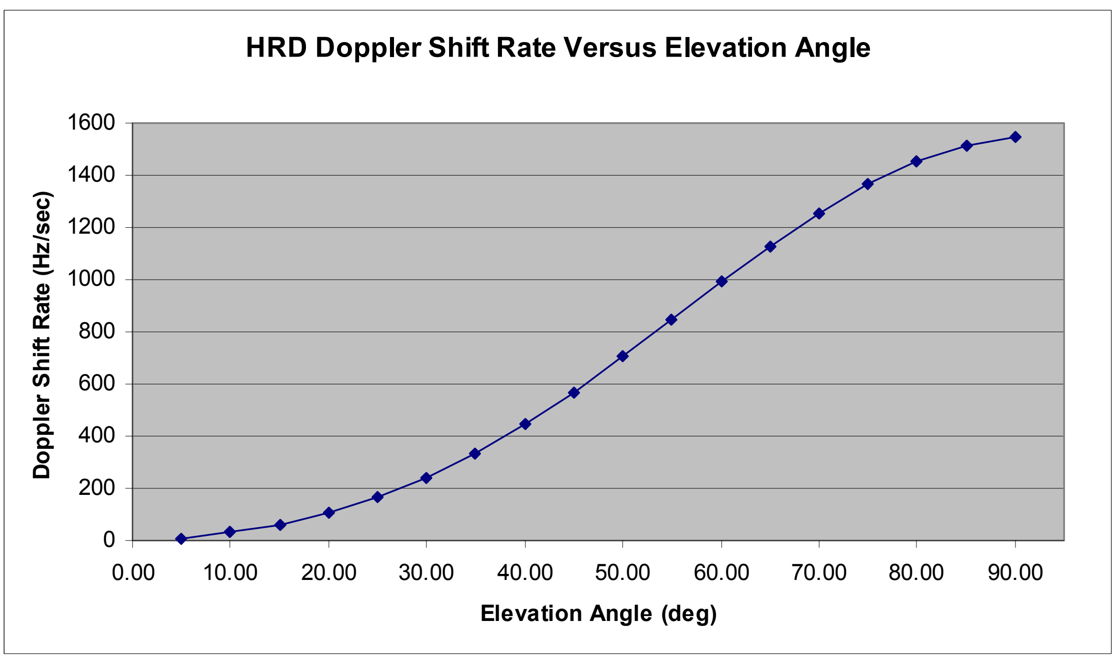


*Figure 4-10 Doppler Shift Rate Versus Elevation Angle*

#### 4.4.2.5 Signal Characteristics-Spurious Emissions

All out-of-band spurious emissions will be less than –53dBc/Hz.

## 4.5 GROUND INTERFACE TESTING

### 4.5.1 HRD Compatibility Test

The NPP Spacecraft will be made available to perform HRD compatibility testing for the purpose of verifying compatibility with the specified HRD ground station. A hard-line RF output from the transmitter and an air link path will be available for this compatibility testing. Figure 4-11 shows that the transfer switch allows for switching between the two configurations with full redundancy checking available. Attenuators will be provided as necessary to interface with the ground test equipment. Additional detail will be available when the scope of the testing is known.

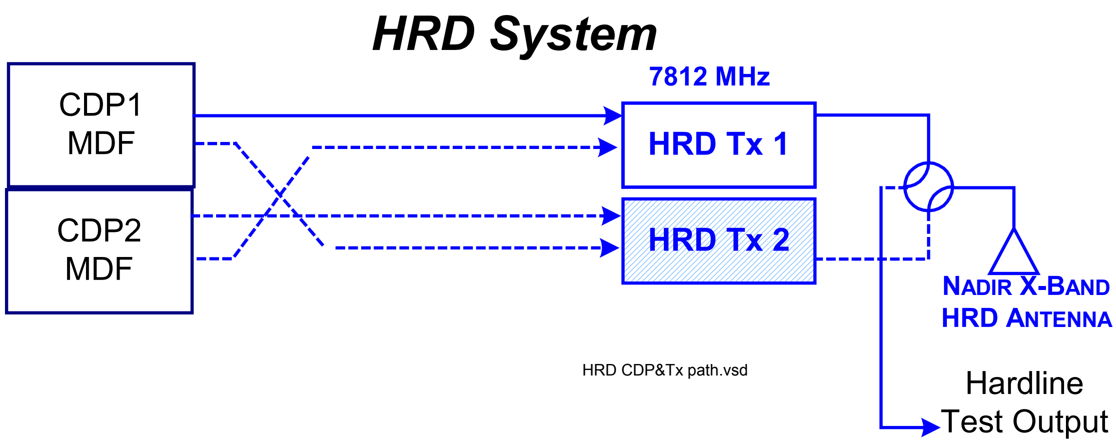


*Figure 4-11 HRD Connection for Compatibility Test*

### 4.5.2 End-to-End Test

For End-to End (ETE) testing during NPP Compatibility Tests (NCTs), HRD data will be flowed from the HRD ingest system at BATC via Gbit Ethernet to the NPOESS factory. HRD data will be sent in a "raw" format with CORBA (TBR) protocol wrapper. This data will be sent in near real-time fashion at the full 15 Mbps rate in NRZ-L format (convolutional coding will have been removed).

## 4.6 HRD SCHEDULING

Data regarding NPP scheduling, ephemeris information, predicted outages, and other user messages will be stored on the NPOESS Mission Support Data Server (MSDS). Authorized Direct Broadcast Users may retrieve mission support data via the internet. The NPOESS MSDS Uniform Resource Locator (URL) will be provided to the Direct Broadcast User upon registration with the NPOESS Program.

## APPENDIX A. RF Link Calculations

| NPP Payload Science Downlink at 15 Mbps (5 deg) | | | | |
|---|---|---|---|---|
| Parameter | Symbol | Value | Unit | Source |
| Frequency | f | 7.812 | GHz | Input Parameter |
| Transmitter Power | p | 7.00 | Watt | Input Parameter |
| Total Transmit Power | P | 38.45 | dBm | P = 10 log(p)+30 |
| S/C Antenna Gain (+/- 61.9°) | Gt | 5.90 | dB | Gain is worst case for +/- 1° pointing |
| Passive Loss | Li | -1.30 | dB | 7 ft coaxial cable loss & switch |
| Equiv. Isotropic Radiated Power | EIRP | 43.05 | dBm | EIRP = P+Gt+Li |
| Propagation Path Length | S | 2835.13 | km | Input Param (5° Elevation Angle) |
| Free Space Dispersion Loss | Ls | -179.3545 | dB | Ls = -92.44 - 20log(S) - 20log(f) |
| Polarization Loss | Lp | -0.20 | dB | Pol loss in antenna gain measurements |
| Rain & Atmospheric Loss | La | -3.65 | dB | HRD IRD Spec |
| Multipath Loss | Lc | -0.20 | dB | HRD IRD Spec |
| Ground Antenna Pointing Loss | | -1.00 | dB | 3 meter ground antenna |
| Ground Station G/T | Grp | 22.70 | dB/K | HRD IRD G/T at 5° elevation angle |
| Total Received Power/T | | -118.65 | dBm/K | |
| Boltzmann's Constant | k | -198.6 | dBm/Hz-K | $k = 10\log(1.38*10^{-23})$ |
| Total Received Power/kT | | 79.95 | dB-Hz | |
| DATA CHANNEL (QPSK) | | | | |
| Data Power/kT | | 79.95 | dBm/Hz/KT | |
| Information Rate | | 71.76 | dB-Hz | 15 Mbps/Channel |
| Available S/N | | 8.19 | dB | |
| Rqd $E_b/N_o$ $10^{-5}$ BER from Viterbi | | 4.40 | dB | From IRD link analysis |
| Implementation Loss | | -2.50 | dB | IRD specified implementation loss |
| **Available Signal Margin** | | **1.29** | **dB** | 1 dB Margin Required |

*Figure A-1: Static Link Analysis*

**TBD**

*Figure A-2: Link Analysis Margin Versus User Terminal Elevation Angle*

## APPENDIX B. Earth-Coverage Antenna Pattern

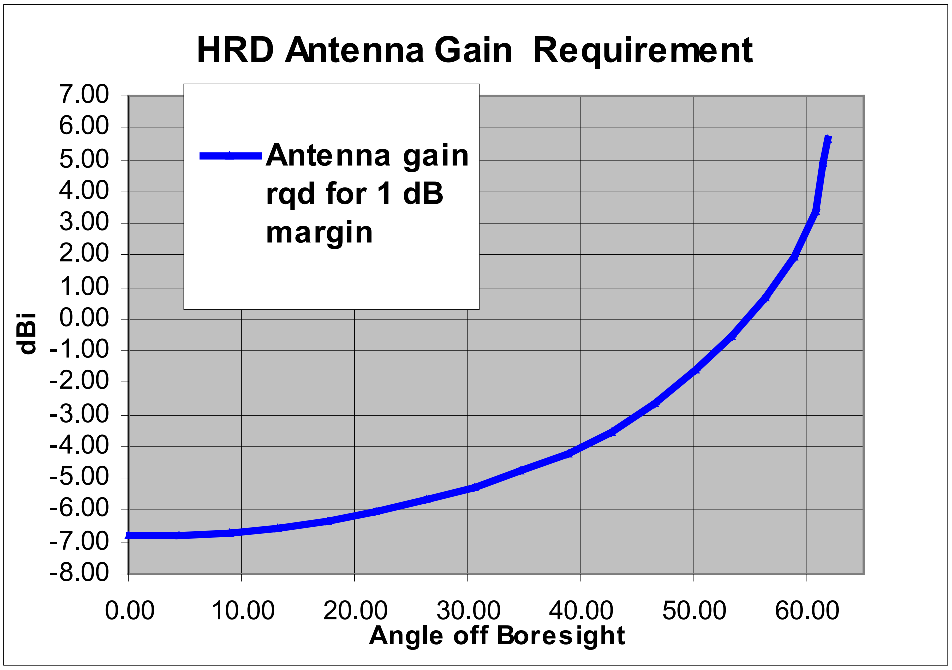


*Figure B-1: Single Sided Antenna Pattern Requirement as a Function of Off point Angle*

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# APPENDIX C. HRD Spectrum

TBD

*Figure C-1 Spectral Plot*

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## APPENDIX D. Acronyms

| | |
|---|---|
| APID | Application Identification |
| AM | Amplitude Modulation |
| | |
| BATC | Ball Aerospace & Technologies Corporation |
| BER | Bit Error Rate |
| | |
| CADU | Channel Access Data Unit |
| CCB | Configuration Control Board |
| CCSDS | Consultative Committee for Space Data Systems |
| CDP | Command and Data Processor |
| CMD | Command |
| cPCI | Compact Peripheral Computer Interface |
| CVCDU | Coded Virtual Channel Data Unit |
| C3S | Command, Control and Communications Segment |
| | |
| dB | Decibel |
| dBc | Decibel Below Unmodulated Carrier |
| dBm | Decibel level is relative to a 1 milliwatt reference |
| dBW | Decibel level is relative to a 1 watt reference |
| DSN | Deep Space Network |
| | |
| EIRP | Effective Isotropic Radiated Power |
| ETE | End-to-End |
| | |
| FSW | Flight Software |
| | |
| GSFC | Goddard Space Flight Center |
| G/T | System Gain-to-Noise Temperature Ratio (dB/$^{O}$ K) |
| | |
| HRD | High Rate Data |
| HTX | HRD Transmitter |
| Hz | Hertz |
| | |
| ICD | Interface Control Document |
| I channel | in-phase channel |
| IPO | Integrated Program Office |
| IRD | Interface Requirements Document |
| | |
| K | Kelvin |

| | |
|---|---|
| kbps | Kilobits per second |
| Kib/s | Kilobits (binary) per Second (ie 32 Kib/s = 32,768 bps) |
| | |
| LVDS | Low Voltage Differential Signal |
| | |
| Mbps | Megabits per Second |
| MHz | Megahertz |
| M_PDU | Multiplexer Protocol Data Unit |
| MSB | Most Significant Bit |
| MSDS | Mission Support Data Server |
| Msps | Megasymbols per second |
| | |
| NASA | National Aeronautics and Space Administration |
| N/A | Not Applicable |
| NCT | NPP Compatibility Test |
| ND | Networks Division |
| NPOESS | National Polar-Orbiting Operational Environmental Satellite System |
| NPP | NPOESS Preparatory Project |
| NRZ | Non-return to Zero |
| NRZ-L | Non-return to Zero Level |
| NRZ-M | Non-return to Zero Mark |
| NTIA | National Telecommunications & Information Administration |
| | |
| PM | Phase Modulation |
| Pol | Polarization |
| p-p | Peak to Peak |
| PRBS | Pseudo Random Bit Stream |
| | |
| Q channel | quadrature-phase channel |
| QPSK | Quadrature Phase Shift Keying |
| | |
| RF | Radio Frequency |
| RFICD | Radio Frequency Interface Control Document |
| RHCP | Right Hand Circular Polarization |
| RMS | Root Mean Square |
| RS | Reed/Solomon |
| | |
| S/C | Spacecraft |
| SMD | Stored Mission Data |
| S/N | Signal to Noise Ratio |
| SSPA | Solid State Power Amplifier |

| | |
|---|---|
| SSPR | Shared System Performance Responsibility |
| synch | synchronizer |
| | |
| TBD | To Be Determined |
| TDRS | Tracking and Data Relay Satellite |
| TDRSS | Tracking and Data Relay Satellite System |
| TLM | Telemetry |
| TCXO | Temperature Compensated Crystal Oscillator |
| | |
| URL | Uniform Resource Locator |
| | |
| VCDU | Virtual Channel Data Unit |

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